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Characterization of Underground Cellars in the Duero Basin by GNSS, LIDAR and GPR Techniques

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1 Introduction

The underground cellars that appear in different parts of Spain are part of an agricultural landscape dispersed, sometimes damaged, others at risk of disappearing.

This paper studies the measurement and display of a group of wineries located in Atauta (Soria), in the Duero River corridor. It is a unique architectural complex, facing rising, built on a smooth hillock as shown in Fig. 1.

These constructions are excavated in the ground. The cellars are nearly straight and arranged in parallel. The access to the cave or underground cellar has a shape of a narrow tube or down gallery. Immediately after, this space gets wider. There, wine is produced and stored [1].

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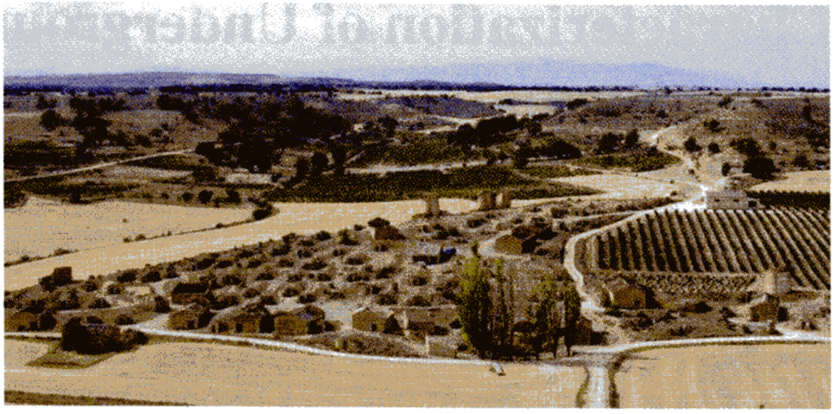


Fig. 1 Underground cellars. Atauta (Soria)

The measurement process and subsequent graph is addressed here and it aims to develop a new methodology according to the instruments used.

Observation and detection of the underground cellar, both on the outside and underground, it is essential to make an inventory of the rural patrimony [2]. The geo-detection is a noninvasive technique, adequate to accurately locate buried structures in the ground. Works undertaken include topographic work with the LIDAR techniques (Laser Imaging Detection and Ranging) and integration with data obtained by GNSS (Global Navigation Satellite System) and GPR (Ground Penetrating Radar). The results obtained are used to identify construction elements which form the underground cellar with an accuracy of centimeters. The graphic and cartographic results enable an optimal visualization of the study area and can be used in the reconstruction of the place.

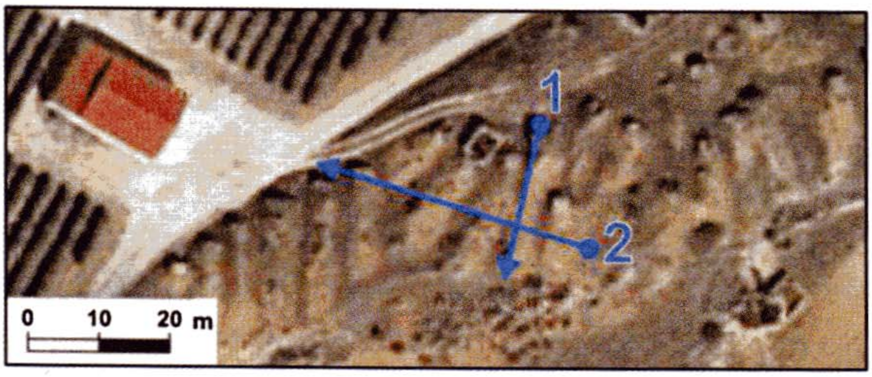
2 Methods

In one of the cellars we made GPR prospecting from the surface and underground LIDAR scanning. The joint use of both techniques facilitates the determination and location of internal structures. LIDAR scanning provides the location of the internal visible structures of the cellar and its position related with surface. Through their fitting with the GPR profile, we estimate the Radio Wave Velocity (RWV) in the ground, required for locating the GPR detections of the hollow parts and old hidden structures.

The radar data were acquired using a Malå Ramac/GPR ProEx system equipped with unshielded antennae of 100 and 200 MHz, in order to compare the behaviour of different frequencies suitable for the area conditions and type of space [3]. Two profiles were done at each frequency, one along the selected cellar (itinerary 1, Fig. 2), and the second transversal to the selected and adjoining cellars (itinerary 2, Fig. 2).

The LIDAR used was a Faro Focus 3D. It was furnished with a telematic unit ambiguity and interval of 153.49 m and a range of 0.5–120 m outdoor with low ambient light. Point clouds registered by LIDAR and GPR where linked using GNSS techniques [4]. Also GNSS was used for georeferencing the entire survey [5].

Fig. 2 Itineraries (1) and (2), both with GPR 100 and 200 MHz



3 Results

Figure 3 shows the 100 MHz GPR transparent profile obtained from the itinerary 1, superimposed on the LIDAR profile. The inner profile of the winery detected by LIDAR is represented in blue (hidden cavities are not detected). The GPR detection is shown in yellow and the road level in white.

We can observe that the dome rests on the road level. Other detectable structures are the chimney pipe (in red), a wide cavity around it, and a discontinuity over the structure that supports the roof stairs. The coupling of the results from GPR and LIDAR lets us estimate a value of 0.13 m/ns for the RWV in the medium (soil and rock), which is appropriate for a reasonably dry limestone. The radar detection profile does not match with the inner cavity detected by the LIDAR. This is due to the early GPR reflections in the hollow parts and old hidden structures, in addition to the limited resolution capability of the 100 MHz GPR, of ca 50 cm. A resonance effect appears in the staircase zone produced by multiple reflections between the stair treads and the ceiling. Over the cellar roof there may be a layer of fractured rock, which can produce a GPR reflection some centimetres above the roof.

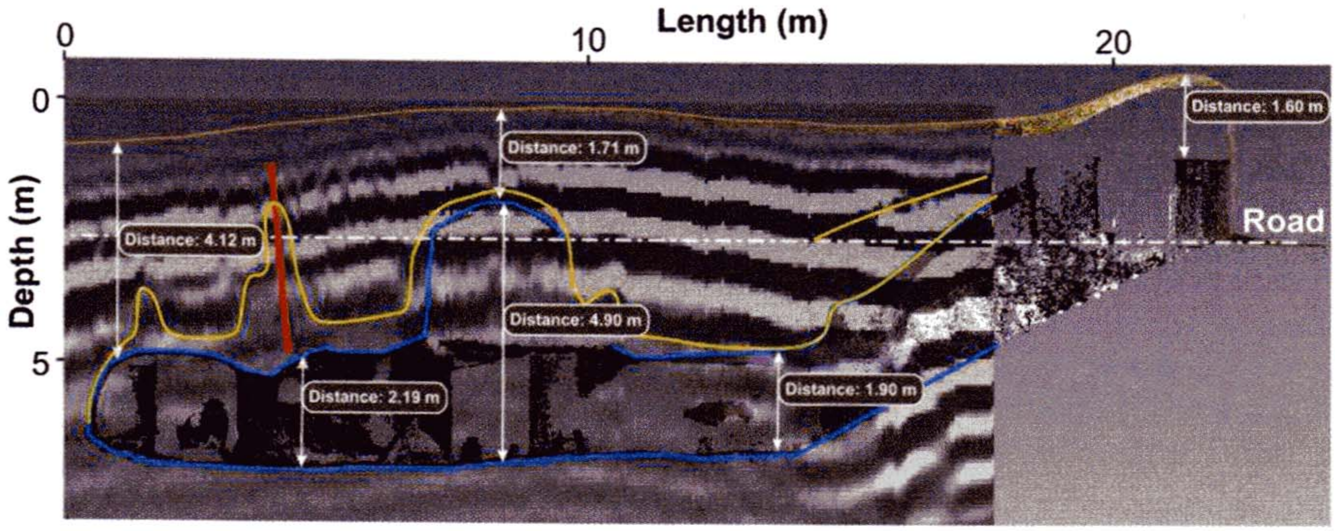


Fig. 3 GPR transparent profile superimposed on the LIDAR profile

4 Conclusions

The use of Geographic Information Technology allows better geovisualization of the rural heritage, as shown on this article.

Using 200 MHz GPR the penetration depth was scarce, while with 100 MHz we have obtained successfully results. It has detected the different cave-domes, the cave-ceiling and most of the cave-floors. It is also possible to detect the presence of other structures, as the entrance beam, the chimney or other close entrances.

The joint use of LIDAR and GPR techniques has revealed a faster method than conventional techniques, such as total station or photogrammetry. Also the RWV estimate is faster and more accurate than using only GPR. The accuracy obtained is centimetric, and GNSS technique makes feasible the combined use of LIDAR and GPR maintaining the accuracy and the survey speed.

The techniques described in this article are suitable to use on other natural cavities, archaeological cavities or multipurpose constructed underground spaces.

This project can help the underground cellars to be declared as Cultural Interest by the *Comisión de Patrimonio Cultural de Castilla y León–Junta de Castilla y León* (Heritage Department of the Regional Government of Castilla y León).

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